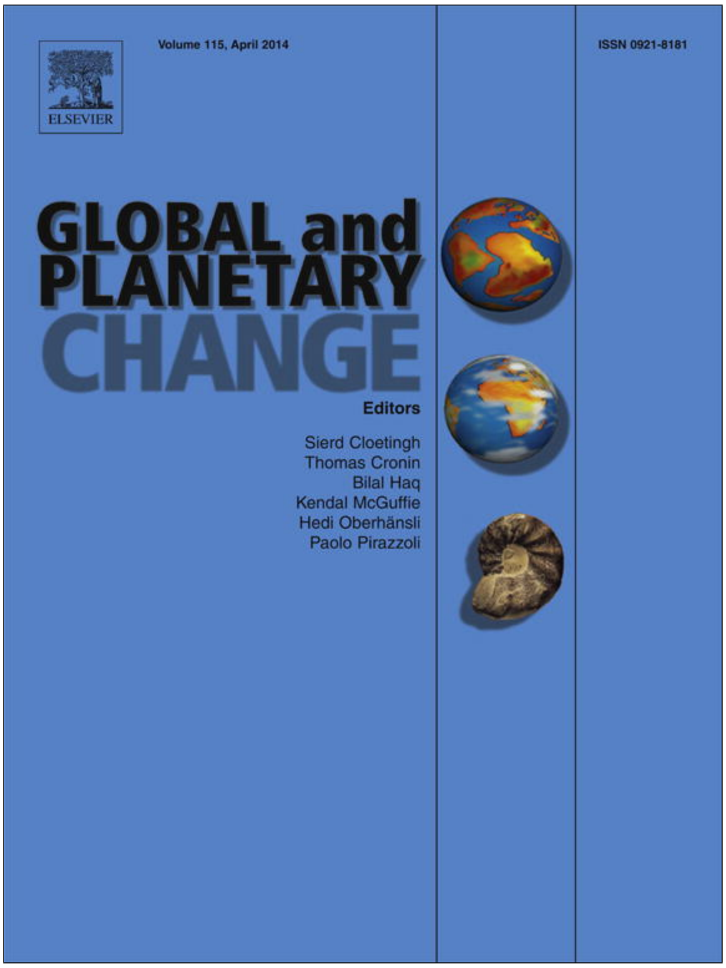
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Sensitivity of evapotranspiration to climatic change in different climates

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ABSTRACT

This paper presents a study of the sensibility of evapotranspiration (ET) to climatic change in four types of climates (i.e., humid, cold semi-arid, warm semi-arid and arid). The use of a reference crop ET (ET_o) permits the standardization of ET estimates across varying conditions. So, ET_o was estimated with the FAO-56 Penman–Monteith equation using data from eight Iranian sites over a 41-year period (1965–2005). The sensitivity analyses were carried out for air temperature, wind speed and sunshine hours within a possible range of ±20% (i.e., −5%, −10%, −20%, +5%, +10%, +20%) from the normal long-term climatic variables. The sensitivity of ET_o to the same climatic variables revealed significant differences among climates. From the comparison of the sensitivity of ET_o to climatic change in different climates, it can be inferred that the sensitivity of ET_o to wind speed and air temperature decreased from arid to humid climate, whereas its sensitivity to sunshine hours increased from arid to humid environment. Furthermore, the greatest change in ET_o (about ±9%) was found in arid climate in response to ±20 change in wind speed.

1. Introduction

The topic of climate change and its impacts have been a key research area in recent years and have attracted much attention of the researchers on various time and space scales in the world. Climate change can be defined as any systematic change in the long-term evolution describing the climate system that is sustained over several decades or longer (Gil-Alana, 2012). Generally, it has been demonstrated that global surface warming has been taking place at a rate of 0.74 ± 0.18 °C over the recent 100-year period (1906–2005) and the warming rate over the last 50 years of this period is almost twice that of the 100-year period (IPCC, 2007).

One major challenge of recent hydrological modeling activities is the assessment of the effects of climate change on the terrestrial water cycle (Bormann, 2011). Climate changes have exerted significant impacts on hydrological parameters, viz. runoff, evapotranspiration (ET), soil moisture, ground water etc. (Goyal, 2004; Yin et al., 2010). Evapotranspiration as the major component of hydrological cycle is influenced by several climatic parameters, viz. air temperature, wind speed, humidity, sunshine hours etc. Any change in climatic parameters due to global warming will affect ET (or crop water requirement) and future planning and management of water resources (Goyal, 2004).

As one of the most important hydrological parameters for scheduling irrigation plan, preparing input data for hydrological water-balance models, and computing actual ET for a watershed, reference evapotranspiration (ET_o) has received a great deal of attention from many international research programmes, e.g. World Climate Research Programme (WCRP), International Geosphere-Biosphere Programme (IGBP), International Human Dimensions Programme on Global Environmental Change (IHDP) and United Nations Educational, Scientific and Cultural Organization (UNESCO) (Liang et al., 2008).

A sensitivity analysis of ET_o to perturbations (all sorts of data errors or, actual climatic changes) associated with one or more climatic variables is important to improve our understanding of the connections between climatic conditions and ET_o variability, and between data availability and estimation accuracy of ET_o (Gong et al., 2006). Results of sensitivity analyses make it possible to determine the accuracy required when measuring climatic variables used to estimate ET_o (Irmak et al., 2006). Several studies of the sensitivity of ET_o have been made to determine the expected change in ET_o in response to a known change in one of the climatic variables (e.g., Ley et al., 1994; Rana and Katerji, 1998; Irmak et al., 2006; Bormann, 2011). Goyal (2004) studied the sensitivity of ET_o to global warming for arid regions of Rajasthan, India. The Penman–Monteith equation was used to estimate ET_o, and sensitivity of ET_o has been investigated in terms of change in temperature, wind speed, vapor pressure and solar radiation within a possible range of ±20% from the normal long-term meteorological parameters of 32 years (1971–2002). The results showed that ET_o is less sensitive to change in net solar radiation, followed by wind speed and vapor pressure in comparison to temperature. Gong et al. (2006) carried out a sensitivity analysis to predict responses of ET_o estimated by the FAO-56 Penman–Monteith equation to perturbations of air temperature, wind speed, relative humidity and sunshine duration in Yangtze River basin in China. ET_o was estimated with the FAO-56 Penman–Monteith equation. They found that relative humidity was the most sensitive variable, followed by shortwave radiation, air temperature and wind speed.

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Table 1
Geographic and climatic characteristics of the study stations.

Station	Latitude (N)	Longitude (E)	Altitude (m)	T (°C)	U (m/s)	n (hr)	ET_o (mm/day)	Climate type
Zahedan	28 29	53 60	1370	18.47	3.19	9.26	5.91	Arid
Yazd	54 31	17 54	1237	19.22	2.59	9.28	5.58	Arid
Shahroud	25 36	57 54	1345	14.64	2.02	8.12	3.92	Warm semi-arid
Semnan	35 35	33 53	1131	18.12	1.37	8.20	3.91	Warm semi-arid
Oroomieh	32 37	05 45	1316	11.22	1.55	7.90	3.10	Cold semi-arid
Tabriz	05 38	17 46	1361	12.59	3.03	7.56	4.18	Cold semi-arid
Rasht	15 37	36 49	−7	15.99	1.20	4.59	2.31	Humid
Bandar-Anzali	28 37	28 49	−26	16.22	3.81	4.92	2.36	Humid

T: Air temperature; U: Wind speed; n: Sunshine hours.

Liang et al. (2008) examined the sensitivity of ET_o to four climate variables of air temperature, wind speed, relative humidity and sunshine hours in Tao'er River Basin of the northeastern China. They showed that relative humidity variable was the most sensitive one in general for the Tao'er River Basin, followed by sunshine hours, wind speed and air temperature. Estevez et al. (2009) analyzed the sensitivity of ET_o values to temperature, relative humidity, solar radiation and wind speed in the semi-arid regions of southern Spain. According to their results, ET_o overestimations were produced using positive errors in temperature, solar radiation and wind speed data, while these errors in relative humidity resulted in ET_o underestimations. Furthermore, the sensitivity of ET_o to the same climatic variables showed significant differences among locations. Ali et al. (2009) studied the sensitivity of the ET_o calculated by the FAO Penman–Monteith equation under the environment of a semi-humid sub-tropic region of Bangladesh. The results indicated that the ET_o estimates are most sensitive to maximum temperature, relative humidity, sunshine duration, wind speed and minimum temperature, respectively.

Iran, mainly an agrarian society is seriously vulnerable to the anthropogenic-induced climate change as most of the geographical area falls under the arid and semi-arid type of climate (Dinpashoh et al., 2011). Changes in climatic regimes due to warming of the earth-atmosphere system may affect agricultural water demand, because ET may be affected by changes in climatic variables (Tabari et al., 2012). It seems very likely that any change in the availability of water will play a key role in the sustainable development of agriculture and environment in Iran (Dinpashoh et al., 2011). In addition, there has been much discussion recently about virtual water trade and the links between hydrology and food security. Iran is considered a highly food insecure nation, largely due to the poor water resources available (Tabari et al., 2012). Thus, assessment of climate change impacts on ET variability can be helpful in determining appropriate adaptation strategies for mitigating the probable damage from these impacts (Shadmani et al., 2012).

The previous researches were limited to a one type of climate, and the studies on the sensitivity of ET_o to climatic variables under different climatic conditions are rare in the literature. Thus, this research was conducted in the context of an on-going project to analyze the sensitivity of the ET_o values estimated by the FAO Penman–Monteith equation to climatic change under four climate conditions viz., humid, cold semi-arid, warm semi-arid and arid. For this purpose, the sensitivity of ET_o was investigated in terms of change in air temperature, wind speed and sunshine hours within a possible range of $\pm 20\%$ from the normal long-term climatic variables over a 41-year period (1965–2005).

2. Data and methods

Iran, with an area of more than 1,648,000 km^2, is located in the southwest of Asia (approximately between 25°00′ N and 38°39′ N latitudes and between 44°00′ E and 63°25′ E longitudes). The two highest mountain systems, the Alborz and the Zagros and two great deserts called Dasht-e Lut and Dasht-e Kavir strikingly affect the climate of Iran. The Alborz and north Zagro Mountains make up the major northern highlands of the country. The Mediterranean-type climate is dominant over the foothills of these ranges, but most of the country is classified as arid or semi-arid according to various climate classifications.

The meteorological parameters for calculating ET_o by the Penman–Monteith method were obtained from eight stations located in four climatic regions for the period 1965–2005. The meteorological data were provided by the Islamic Republic of Iran Meteorological Organization (IRIMO). The selected stations are located in different climates. According to the Koppen climate classification, Zahedan and Yazd weather stations are in arid climate, Semnan and Shahroud weather stations in warm semi-arid climate, Tabriz and Oroomieh weather stations in cold semi-arid climate and Bandar-Anzali and Rasht weather stations in humid climate (which located on the southern cost of the Caspian Sea). The geographic and climatic characteristics of the selected stations are presented in Table 1.

The International Commission for Irrigation and Drainage (ICID) and Food and Agriculture Organization of the United Nations (FAO) have proposed using the Penman–Monteith method as the standard method for estimating ET_o (Allen et al., 1994a,b). In addition, numerous researchers have accepted this model as the most precise for estimating ET_o in various climates throughout the world (e.g., Trajkovic et al., 2003; Garcia et al., 2004; Popova et al., 2006; Sabziparvar et al., 2010; Sentelhas et al., 2010; Tabari, 2010; Tabari and Hosseinzadeh Talaee, 2011; Tabari et al., 2013). The Penman–Monteith method assumes the ET_o as that from a hypothetical crop with an assumed crop height (0.12 m) and a fixed canopy resistance (70 sm^{-1}) and albedo (0.23), closely resembling the evapotranspiration from an extensive surface of green grass cover of uniform height, actively growing, and not short of water, which is given by Allen et al. (1998) as follows:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T_{mean}+273}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (1)$$

Table 2
Sensitivity of ET_o to climatic change in arid climate.

Station	Climatic variables	Change in ET_o (%) with respect to change in climatic variables					
		−20%	−10%	−5%	+5%	10%	20%
Yazd	T	−6.36	−3.20	−1.49	2.08	3.98	7.99
	U	−8.94	−4.25	−1.99	2.43	4.56	8.74
	n	−1.90	−0.83	−0.30	0.79	1.32	2.23
Zahedan	T	−5.36	−2.63	−1.19	1.83	3.41	6.73
	U	−8.58	−4.05	−1.85	2.40	4.43	8.40
	n	−2.22	−0.96	−0.34	0.93	1.54	2.65
Average	T	−5.86	−2.92	−1.34	1.96	3.70	7.36
	U	−8.76	−4.15	−1.92	2.42	4.50	8.57
	n	−2.06	−0.90	−0.32	0.86	1.43	2.44

T: Air temperature; U: Wind speed; n: Sunshine hours.

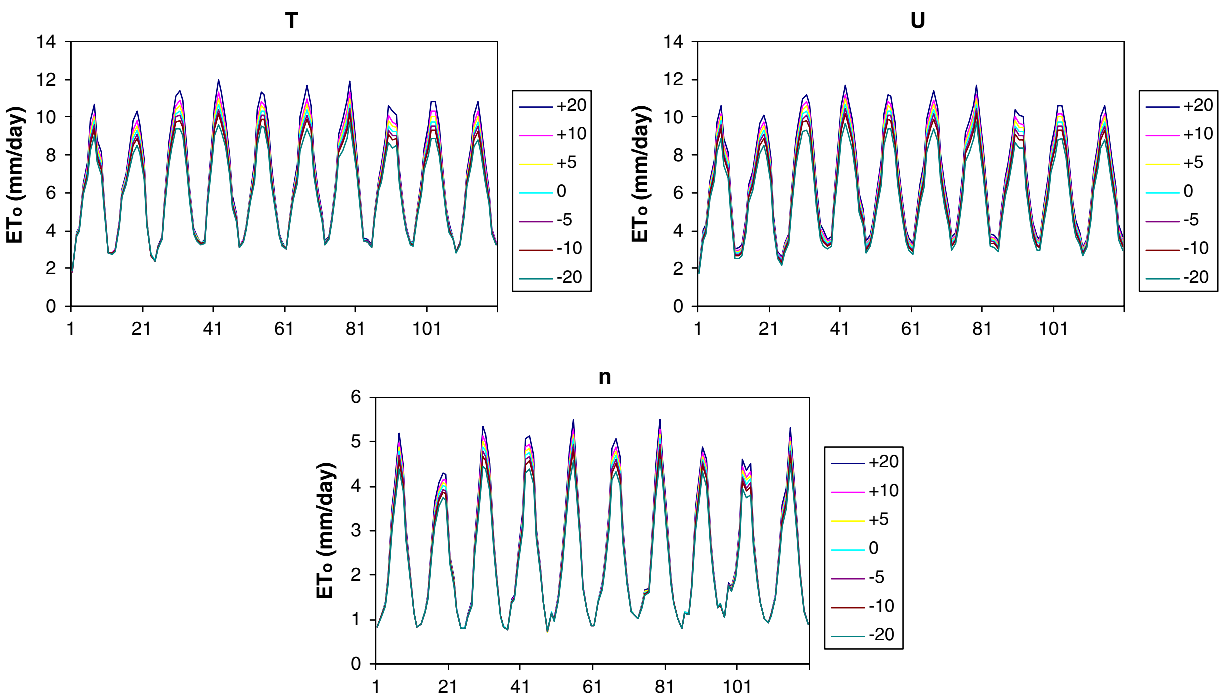

Fig. 1. The estimated monthly ET_o at Zahedan arid station in response to expected change in each climatic variable due to climatic change.

where ET_o is the reference crop evapotranspiration (mm day^{-1}), R_n is the net radiation (MJ m^{-2} day^{-1}), G is the soil heat flux (MJ m^{-2} day^{-1}), γ is the psychrometric constant (kPa °C^{-1}), e_s is the saturation vapor pressure (kPa), e_a is the actual vapor pressure (kPa), and Δ is the slope of the saturation vapor pressure–temperature curve (kPa °C^{-1}), T_{mean} is the average daily air temperature (°C), and U_2 is the mean daily wind speed at 2 m height (m s^{-1}). It should be noted that the 24-h wind speed was recorded at a 10 m height at the study stations, and the necessary corrections were applied to determine its values at a 2 m height.

The parameters Δ and γ were computed as (Allen et al., 1998):

$$\Delta = \frac{4098 e_s}{(237.3 + T_{min})^2} \tag{2}$$

$$\gamma = 0.0016286 \frac{P}{\lambda} \tag{3}$$

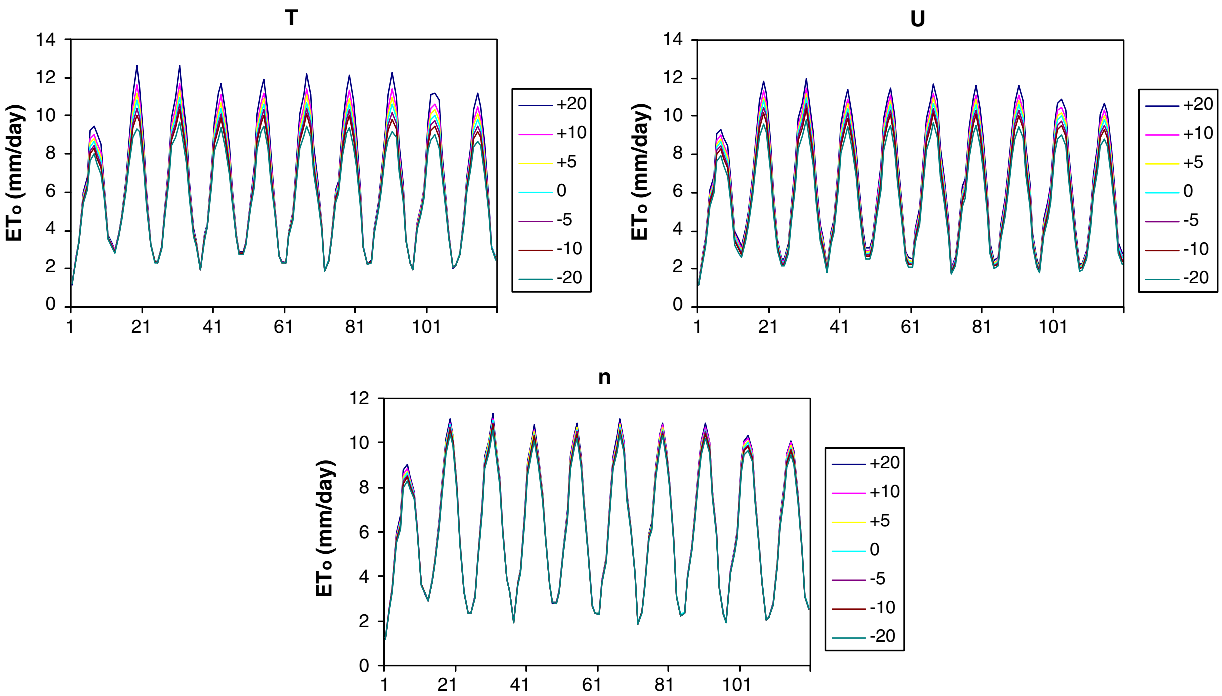

Fig. 2. The estimated monthly ET_o at Yazd arid station in response to expected change in each climatic variable due to climatic change.

Table 3
Sensitivity of ET_o to climatic change in warm semi-arid climate.

Station	Climatic variables	Change in ET_o (%) with respect to change in climatic variables					
		−20%	−10%	−5%	+5%	10%	20%
Semnan	T	−3.70	−2.04	−1.15	0.79	1.82	4.03
	U	−6.94	−3.53	−1.86	1.42	3.02	6.17
	n	−3.98	−2.09	−1.15	0.74	1.68	3.52
Shahroud	T	−2.94	−1.52	−0.77	0.82	1.67	3.42
	U	−6.78	−3.32	−1.63	1.63	3.22	6.32
	n	−3.50	−1.74	−0.86	0.89	1.77	3.50
Average	T	−3.32	−1.78	−0.96	0.81	1.75	3.73
	U	−6.86	−3.43	−1.75	1.53	3.12	6.25
	n	−3.74	−1.92	−1.01	0.82	1.73	3.51

T: Air temperature; U: Wind speed; n: Sunshine hours.

where P is the atmospheric pressure (kPa) and λ is the latent heat of vaporization ($MJ\,kg^{-1}$). The parameters λ and e_a were also computed as

$$\lambda = 2.501 - 0.0002631.T_a \qquad (4)$$

$$e_s = 0.6108 \exp\left(\frac{17.27T_{dew}}{237.3 + T_{dew}}\right) \qquad (5)$$

where T_{dew} is the dew point temperature (°C) (Allen et al., 1998).

A detailed analysis of the Penman–Monteith equation used to estimate ET_o reveals that most of its components are directly related to meteorological variables, and consequently are affected by climatic variability. Wind speed, for instance, can affect the rate of evapotranspiration or the magnitude of water demands. If wind is blowing with higher intensity, evaporation rate will be greater because it weakens the boundary layer and mass transport becomes more efficient, particularly in turbulent flow. There are several mechanisms by which ET_o could be affected by different climatic conditions. It would be theoretically possible to assess the impact of individual changes in these variables by performing a sensitivity analysis (Meza, 2005).

Sensitivity of monthly evapotranspiration at each study station was quantified with respect to air temperature, wind speed and sunshine hours. Sensitivity analyses were conducted by making a ±20% (i.e., −5%, −10%, −20%, +5%, +10%, +20%) change in each climatic variable assuming other variables were fixed. Each variable was increased and decreased for each month for a period of 41 years (1965–2005). First, the base ET_o values were calculated using the base (original climate data without any change) measured climatic variables. Then, each climate variable was increased and decreased individually and a new set of ET_o values were calculated. The amount of increase and decrease in each climate variable was the same for each month and location. For each study station, 41 years of base and new monthly ET_o values were compared and the change in ET_o was computed.

3. Results and discussion

3.1. Arid environment

The amount of percent change in ET_o with respect to change in each climate variable in arid climate is given in Table 2. Also, the estimated monthly ET_o at arid stations in response to expected change in each climatic variable due to climatic change is presented in Figs. 1 and 2. For better illustration of the estimated ET_o values, only the monthly values in the last decade (1996–2005) are shown in the figures. According to the obtained results, increasing air temperature by 5%, 10% and 20% increased ET_o by about 2%, 3.7% and 7.4% in arid climate, respectively. The increase in air temperature affects ET_o primarily by increasing the capacity of air to hold water vapor (Liang et al., 2008). In contrast, decreasing air temperature by 5%, 10% and 20% decreased ET_o by about 1.3%, 2.9% and 5.9%, respectively. ET_o in the arid climate was more sensitive to the increase of temperature than the decrease of it. These results are in good agreement with the results of Goyal (2004) in the arid zone of India. When wind speed was increased by 5%, 10% and 20%, the resulting annual average increases in ET_o in arid climate were 2.4%, 4.5% and 8.6%, respectively. The decreases in ET_o with respect to the decrease in wind speed by 5%, 10% and 20% were 1.9%, 4.2%, and 8.8%, respectively. Moreover, a 5%, 10% and 20% increase in

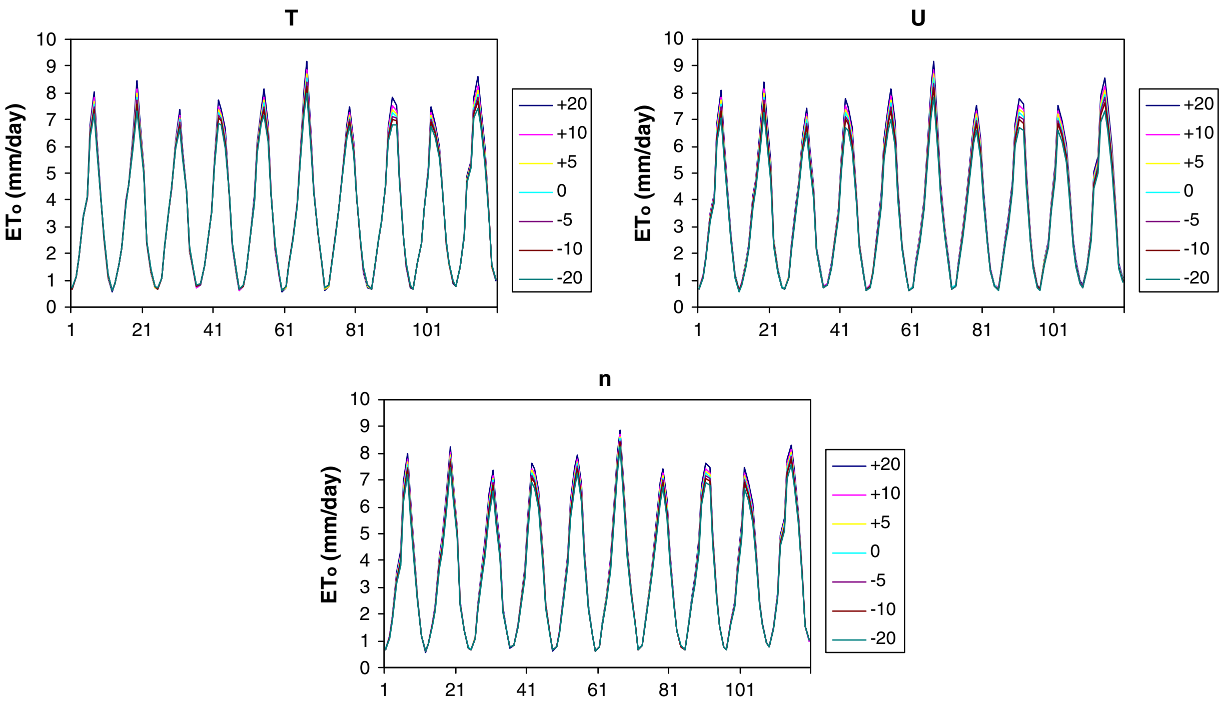

Fig. 3. The estimated monthly ET_o at Shahroud warm-semi arid station in response to expected change in each climatic variable due to climatic change.

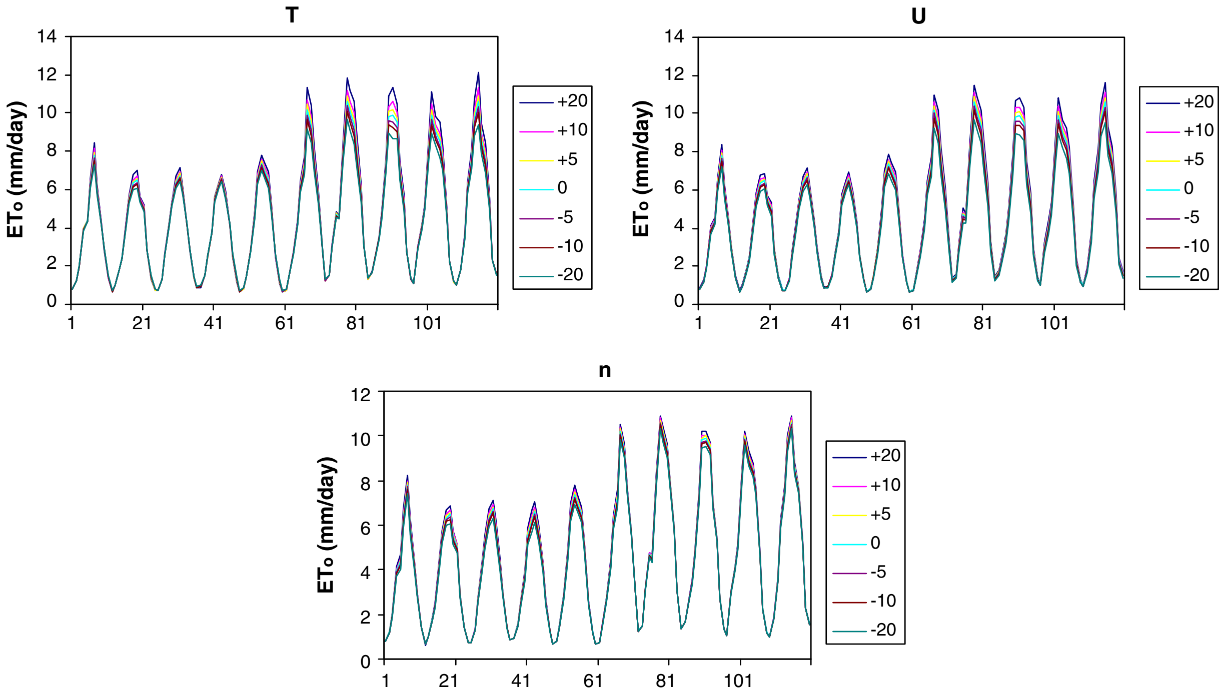

Fig. 4. The estimated monthly ET_o at Semnan warm-semi arid station in response to expected change in each climatic variable due to climatic change.

sunshine hours could cause approximately a 0.9%, 1.4% and 2.4% increase in ET_o in arid climate respectively, whereas a 5%, 10% and 20% decrease in the variable could cause approximately a 0.3%, 0.9% and 2.1% decrease in ET_o, respectively. In general, evapotranspiration in the arid climate was most sensitive to wind speed and air temperature respectively, whereas it was least sensitive to sunshine hours. Goyal (2004) found that evapotranspiration in the arid zone of Rajasthan (India) was most sensitive to changes in air temperature and least sensitive to vapor pressure changes.

3.2. Warm semi-arid environment

Table 3 presents the amount of percent change in ET_o with respect to change in each climate variable in warm semi-arid climate. Also, Figs. 3 and 4 show the estimated monthly ET_o values at warm semi-arid stations in response to expected change in each climatic variable due to climatic change. The results suggest an increase of 0.81%, 1.8% and 3.7% of ET_o with respect to increase in air temperature by 5%, 10% and 20%, respectively. Inversely, ET_o decreased at the rates of 0.96%, 1.8% and 3.3% in response to decrease in air temperature by 5%, 10% and 20%, respectively. A 5%, 10% and 20% increase in wind speed could cause approximately a 1.5%, 3.1% and 6.3% increase in ET_o, respectively. In contrast, decreasing wind speed by 5%, 10% and 20% over normal could result in reduction in ET_o by 1.8%, 3.4% and 6.9%, respectively. The results also indicated that the increase of 5%, 10% and 20% in sunshine hours induced ET_o to increase 0.8%, 1.7% and 3.5% respectively, while the decrease of 5%, 10% and 20% in sunshine hours induced ET_o to decrease 1%, 1.9% and 3.7% respectively. Liang et al. (2008) reported that a sunshine hour-increase of 10% may increase ET_o from 2.0% to 3.1% in a semi-arid area in China. Generally speaking, changes in wind speed had the greatest contribution to changes in evapotranspiration in the warm semi-arid climate, while the change of air temperature and sunshine hours had less effect on evapotranspiration. Irmak et al. (2006) also found that evapotranspiration was more sensitive to wind speed than air temperature in the semi-arid climate of Texas, USA. They showed that a 10% change in wind speed can cause approximately 3.2% change in ET_o in semi-arid climate which is consistent with the results of this study.

3.3. Cold semi-arid environment

The amount of percent change in ET_o in response to change in each climate variable in coldsemi-arid environment is presented in Table 4. Also, the estimated monthly ET_o at cold semi-arid stations with respect to expected change in each climatic variable due to climatic change is illustrated in Figs. 5 and 6. Change in ET_o with respect to change in each variable showed considerable variations among variables. Increase of 5%, 10% and 20% in air temperature could result in increase in total ET_o by 0.6%, 1.2% and 2.4%, respectively. Annual ET_o would reduce 0.5%, 1.0% and 2.1% if air temperature decreased 5%, 10% and 20% respectively and the other climatic variables remained fixed. The amounts of increase in ET_o were 1.4%, 2.6% and 5.6% when wind speed was increased by 5%, 10% and 20%, respectively. In contrast, decrease in wind speed by 5%, 10% and 20% could result in decrease of ET_o by 1.5%, 3.0% and 6.2%, respectively. According to the obtained results, a 5%, 10% and 20% increase in sunshine hours led to a 1.0%, 1.9% and 3.6% increase in ET_o respectively, while decrease in the variable at the same magnitudes led to a 0.9%, 1.9% and 3.8% decrease in ET_o, respectively. Overall, change in wind speed resulted in the largest change in evapotranspiration in the cold semi-arid

Table 4
Sensitivity of ET_o to climatic change in cold semi-arid climate.

Station	Climatic variables	Change in ET_o (%) with respect to change in climatic variables					
		−20%	−10%	−5%	+5%	10%	20%
Tabriz	T	−3.95	−1.99	−0.96	1.19	2.31	4.63
	U	−7.49	−3.64	−1.80	1.77	3.47	6.75
	n	−2.88	−1.39	−0.65	0.84	1.58	3.00
Oroomieh	T	−0.15	−0.09	−0.07	−0.01	0.04	0.15
	U	−4.80	−2.39	−1.20	1.10	2.22	4.42
	n	−4.61	−2.33	−1.19	1.10	2.24	4.24
Average	T	−2.05	−1.04	−0.52	0.59	1.18	2.39
	U	−6.15	−3.02	−1.50	1.44	2.85	5.59
	n	−3.75	−1.86	−0.92	0.97	1.91	3.62

T: Air temperature; U: Wind speed; n: Sunshine hours.

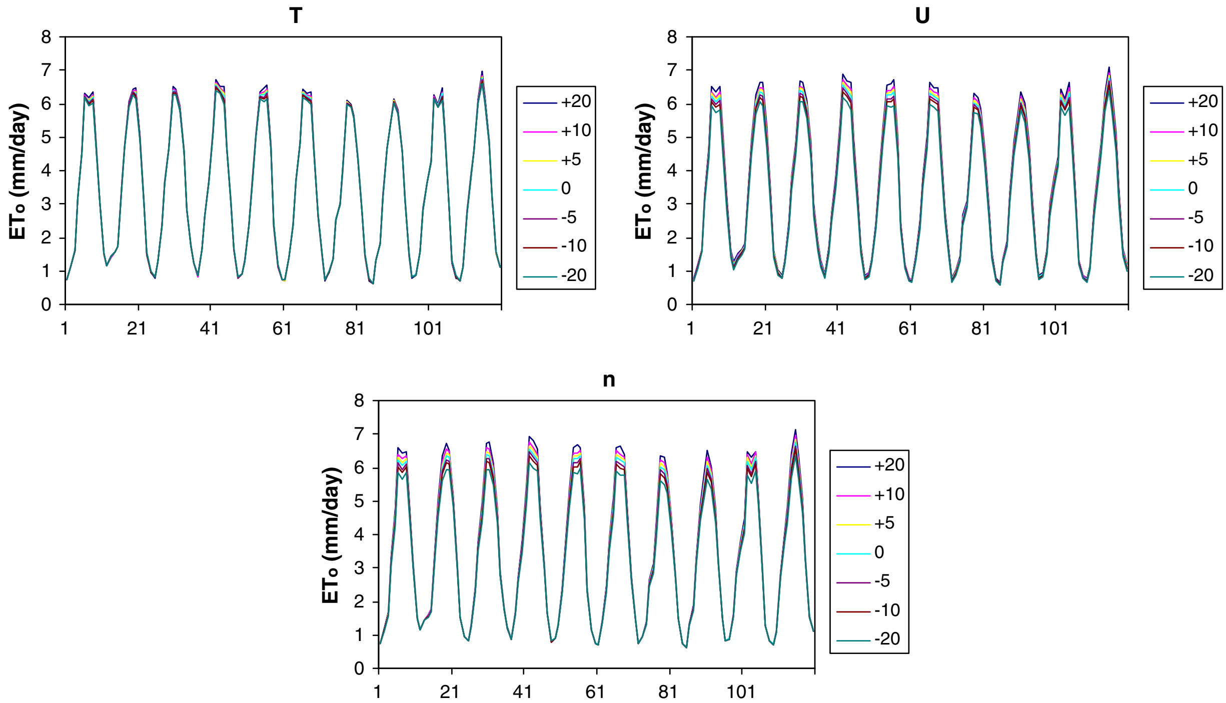

Fig. 5. The estimated monthly ET_o at Oroomieh cold-semi arid station in response to expected change in each climatic variable due to climatic change.

climate and change in air temperature caused the smallest change in evapotranspiration.

3.4. Humid environment

The results of the sensitivity of monthly ET_o to climatic change (Table 5 and Figs. 7 and 8) indicated that decreasing air temperature by 5%, 10% and 20% decreased ET_o by about 2.6%, 3.4% and 5.1% in humid climate, respectively. A 5% and 10% increase of air temperature resulted even in decrease of ET_o by 1.0% and 0.3%, respectively. A 20% increase in air temperature had a small positive effect on ET_o (1.2%). With respect to decrease in wind speed by 5%, 10% and 20%, the decreases in ET_o were 2.3%, 2.8% and 3.9%, respectively. Similar to air temperature, a 5% and 10% increase in wind speed led to a 1.3% and 0.8% decrease in ET_o in humid climate, respectively. The amount of ET_o slightly increased (0.12%) when wind speed was increased by 20%. A 5%, 10% and 20% decrease in sunshine hours could cause approximately a 3.1%, 4.2% and 6.5% decrease in ET_o, respectively. Furthermore, a 5% increase of sunshine hours resulted even in marginal decrease of ET_o by 0.6%. When sunshine hours variable was increased by 10% and 20%, the

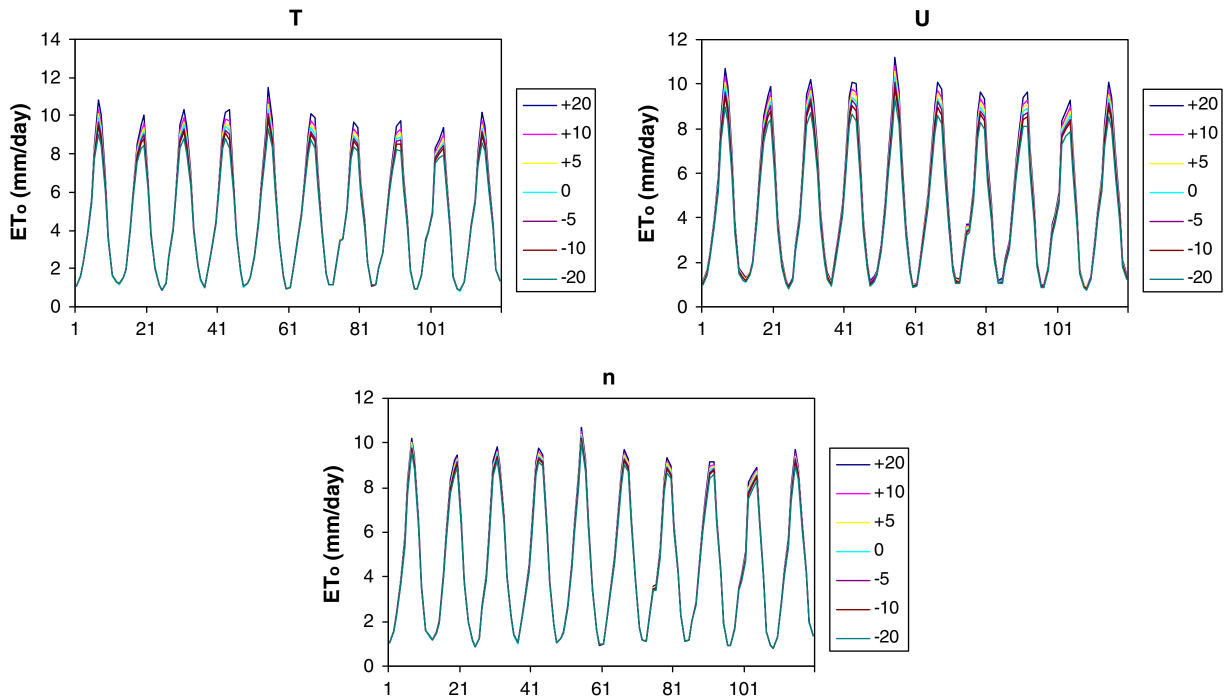

Fig. 6. The estimated monthly ET_o at Tabriz cold-semi arid station in response to expected change in each climatic variable due to climatic change.

Table 5
Sensitivity of ET_o to climatic change in humid climate.

Station	Climatic variables	Change in ET_o (%) with respect to change in climatic variables					
		−20%	−10%	−5%	+5%	10%	20%
Bandar-Anzali	T	−4.66	−3.12	−2.35	−0.86	−0.14	1.27
	U	−3.59	−2.58	−2.10	−1.13	−0.66	0.24
	n	−6.74	−4.17	−3.10	−0.33	0.95	3.51
Rasht	T	−5.50	−3.74	−2.88	−1.22	−0.42	1.14
	U	−4.19	−3.10	−2.58	−1.53	−1.01	−0.01
	n	−6.28	−4.20	−3.15	−0.95	0.09	2.19
Average	T	−5.08	−3.43	−2.62	−1.04	−0.28	1.21
	U	−3.89	−2.84	−2.34	−1.33	−0.84	0.12
	n	−6.51	−4.19	−3.13	−0.64	0.52	2.85

T: Air temperature; U: Wind speed; n: Sunshine hours.

resulting annual average increases in ET_o were 0.5% and 2.9%, respectively. Generally, sunshine hours variable had the most effect on ET_o in the humid climate, while the least effect was obtained for wind speed.

Comparison of the sensitivity of evapotranspiration to climatic change in different climates showed that the sensitivity of evapotranspiration to wind speed decreased from arid to humid climate. The greater impact of wind on evapotranspiration can be explained by the lower amount of water vapor carried by the wind in drier climates as compared to the higher humidity of the wind flow in humid climates (Estevez et al., 2009). Irmak et al. (2006) pointed out that wind speed affects ET_o rate to a far lesser extent in humid climates than under arid conditions, where small variations in wind speed may result in larger variations in ET_o rate. Similar to the pattern of wind speed, evapotranspiration was most sensitive to air temperature in arid climate as compared to semi-arid and humid climates. In contrast to the pattern of wind speed and air temperature, the sensitivity of evapotranspiration to sunshine hours increased from arid to humid environment. Relatively great sensitivity of evapotranspiration to sunshine hours can be explained by the fact that sunshine hours variable is used to estimate solar radiation to calculate ET_o. Irmak et al. (2006) also reported the greatest sensitivity of ET_o to solar radiation at the most humid location among their studied stations.

4. Conclusions

In this study, the sensitivity of the ET_o values estimated by the FAO Penman–Monteith equation to climatic change in different climatic regions of Iran was investigated. Four types of climates including humid, cold semi-arid, warm semi-arid and arid were studied using data form eight weather stations over a 41-year period (1965–2005). For the analysis, the sensitivity of ET_o was investigated in terms of change in air temperature, wind speed and sunshine hours within a possible range of ±20% from the normal long-term climatic variables. The results indicated that the sensitivity of evapotranspiration to wind speed decreased from arid to humid climate. In response to the change in wind speed by ±20%, ET_o varied between ±9% in arid climate. Similar to the pattern of wind speed, evapotranspiration was most sensitive to air temperature in arid climate as compared to semi-arid and humid climates. With respect to a ±20% change in air temperature, the changes in ET_o were more than 5% in arid climate. In contrast to the pattern of wind speed and air temperature, the sensitivity of evapotranspiration to sunshine hours increased from arid to humid environment. A 20% decrease in sunshine hours caused approximately a 6.5% decrease in ET_o in humid climate.

Overall, the findings of this study showed that evapotranspiration responded differently to climatic change in various climatic regions. The results obtained can be used to predict evapotranspiration demand in response to expected change in climatic variables due to climate change. Moreover, the results presented here should be useful to determine the measurement accuracy needed for computing ET_o in different climatic conditions. As an example, to obtain accurate ET_o values in an arid climate it is important to measure wind speed with more accuracy than air temperature.

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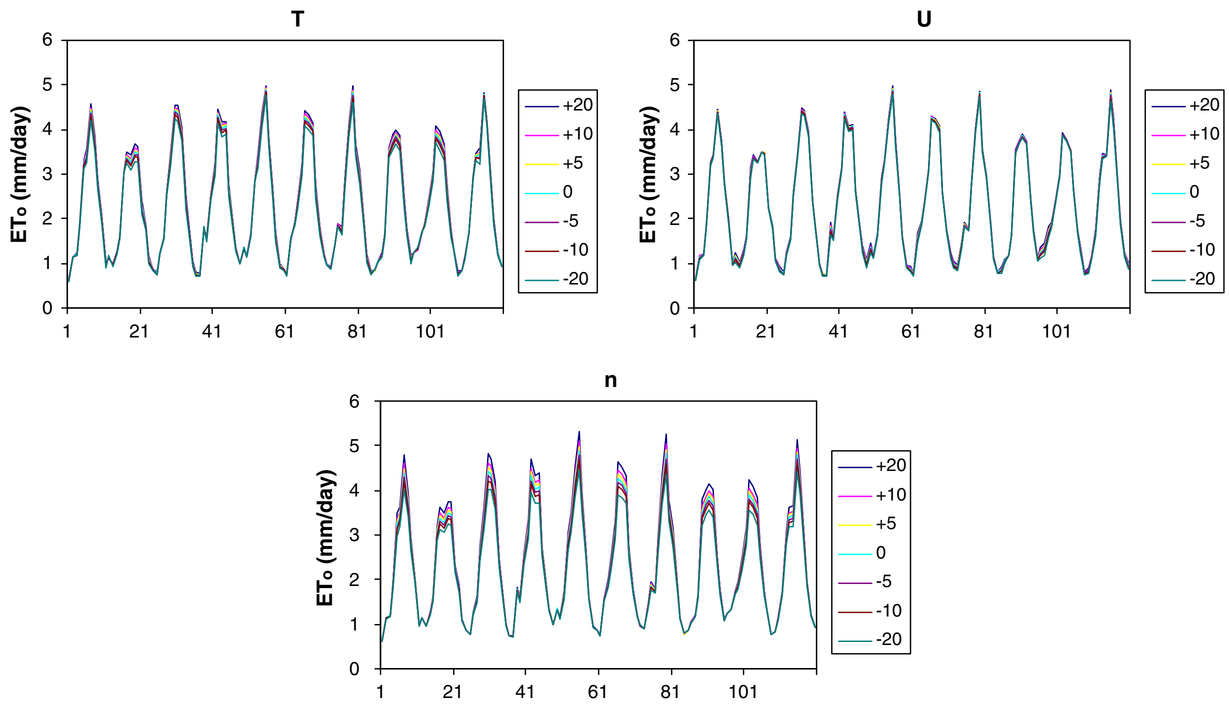

Fig. 7. The estimated monthly ET_o at Rasht humid station in response to expected change in each climatic variable due to climatic change.

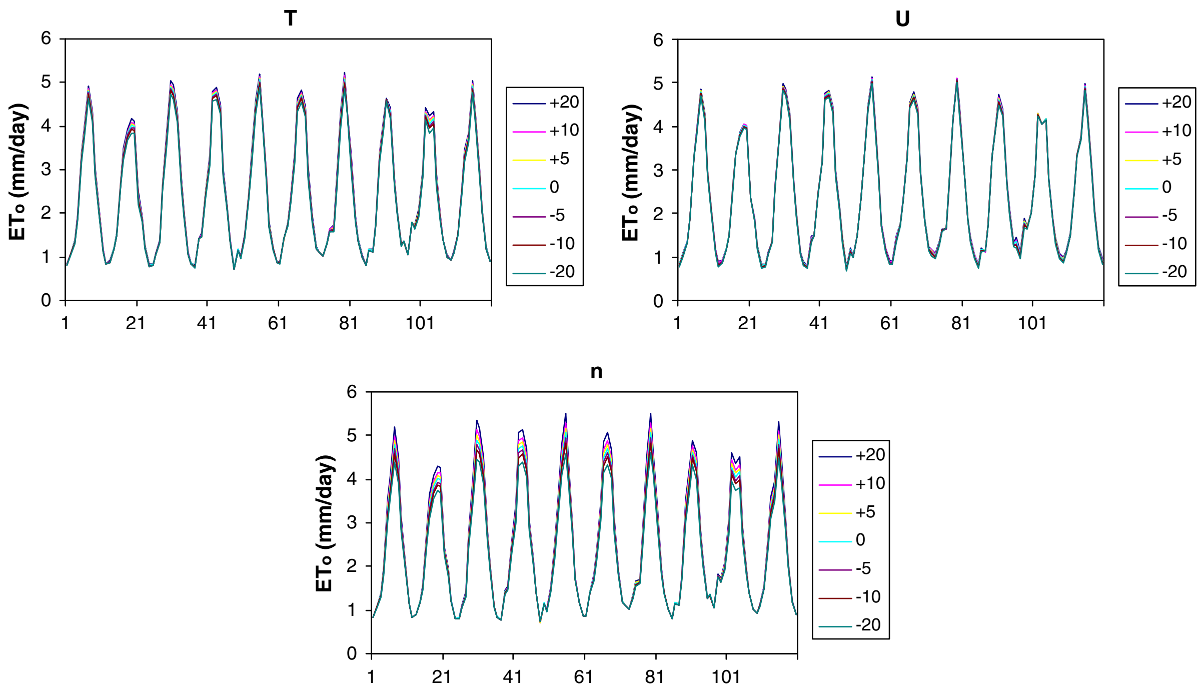

Fig. 8. The estimated monthly ET_o at Bandar-Anzali humid station in response to expected change in each climatic variable due to climatic change.

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